US009321092B2

(12) **United States Patent**
Takasue et al.

(10) **Patent No.: US 9,321,092 B2**
(45) **Date of Patent: Apr. 26, 2016**

(54) **METHOD FOR FORMING STEEL SHEET BY HOT PRESSING**

(75) Inventors: **Tekkan Takasue**, Hiroshima (JP); **Kyousou Ishida**, Hiroshima (JP); **Kouji Hironaka**, Hiroshima (JP); **Takuya Yamazaki**, Hiroshima (JP); **Kenichi Hatakeyama**, Hiroshima (JP); **Shinichiro Kurusu**, Hiroshima (JP); **Akihiro Nakashima**, Hiroshima (JP); **Toshiharu Nakashima**, Hiroshima (JP)

(73) Assignees: **MAZDA MOTOR CORPORATION**, Hiroshima (JP); **IMANISHI MANUFACTURING CO., LTD.**, Hiroshima (JP); **SEKISOU KANAGATA CO., LTD.**, Hiroshima (JP); **KEYLEX CORPORATION**, Hiroshima (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 198 days.

(21) Appl. No.: **13/810,623**

(22) PCT Filed: **Jun. 21, 2011**

(86) PCT No.: **PCT/JP2011/003537**

§ 371 (c)(1),
(2), (4) Date: **Jan. 16, 2013**

(87) PCT Pub. No.: **WO2012/011224**

PCT Pub. Date: **Jan. 26, 2012**

(65) **Prior Publication Data**

US 2013/0111966 A1 May 9, 2013

(30) **Foreign Application Priority Data**

Jul. 21, 2010 (JP) 2010-163717

(51) **Int. Cl.**
B21D 22/02 (2006.01)

(52) **U.S. Cl.**
CPC ***B21D 22/022*** (2013.01); ***B21D 22/02*** (2013.01)

(58) **Field of Classification Search**
CPC B21D 22/02; B21D 22/022; B21D 24/005; B21D 24/16
USPC 72/342.2, 342.5, 348, 353.2, 354.2, 72/356, 357, 360, 361, 384, 405.01
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2004/0163439 A1 8/2004 Arns et al.
2004/0250585 A1 12/2004 Bennett et al.

(Continued)

FOREIGN PATENT DOCUMENTS

CN 101104184 A 1/2008
DE 10307184 B3 4/2004

(Continued)

OTHER PUBLICATIONS

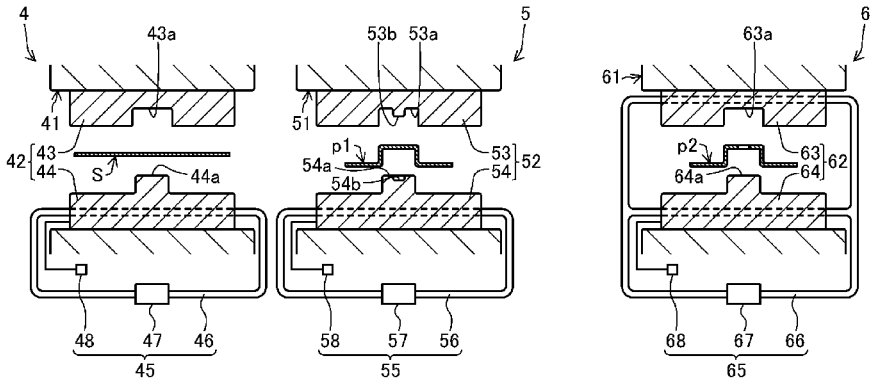
International Searching Authority, International Search Report and Written Opinion for International Application No. PCT/JP2011/003537, mailed Aug. 2, 2011, 10 pages, Japanese Patent Office, Japan.

Primary Examiner — Debra Sullivan
(74) *Attorney, Agent, or Firm* — Alston & Bird LLP

(57) **ABSTRACT**

Consumed energy is minimized to reduce running cost. Final formed products of uniform quality are successively obtained. High productivity is provided. A primary forming step of obtaining a primary formed product by plastically working a heated steel sheet with a primary forming die set for a predetermined time period, a secondary forming step of machining the primary formed product with the secondary forming die set for a predetermined time period to obtain a secondary formed product, and a hardening step of allowing a cooling die set placed in a hydraulic press controlled by a servomotor to hold the secondary formed product under pressure for a longer time period than the time period of each of the primary and secondary forming steps to obtain a hardened final formed product are successively performed in sequence. The hardening step is performed independently without coordinating with the primary and secondary forming steps.

5 Claims, 14 Drawing Sheets



(56) **References Cited**

U.S. PATENT DOCUMENTS

2008/0134909	A1	6/2008	Kohno	
2008/0173057	A1*	7/2008	Kruger et al.	72/342.7
2010/0307216	A1*	12/2010	De Souza et al.	72/342.8

FOREIGN PATENT DOCUMENTS

DE	602004013264	T2	5/2009
JP	4-028500	A	1/1992
JP	7-037484	U	7/1995
JP	2000/254799	A	9/2000
JP	2003-145224	A	5/2003
JP	2005-059010	A	3/2005
JP	2005/248253	A	9/2005
JP	2005-262235	A	9/2005
JP	2006/192458	A	7/2006
JP	2007/136533	A	6/2007
JP	2007/136534	A	6/2007
JP	2008-264853	A	11/2008
JP	2009-072801	A	4/2009

* cited by examiner

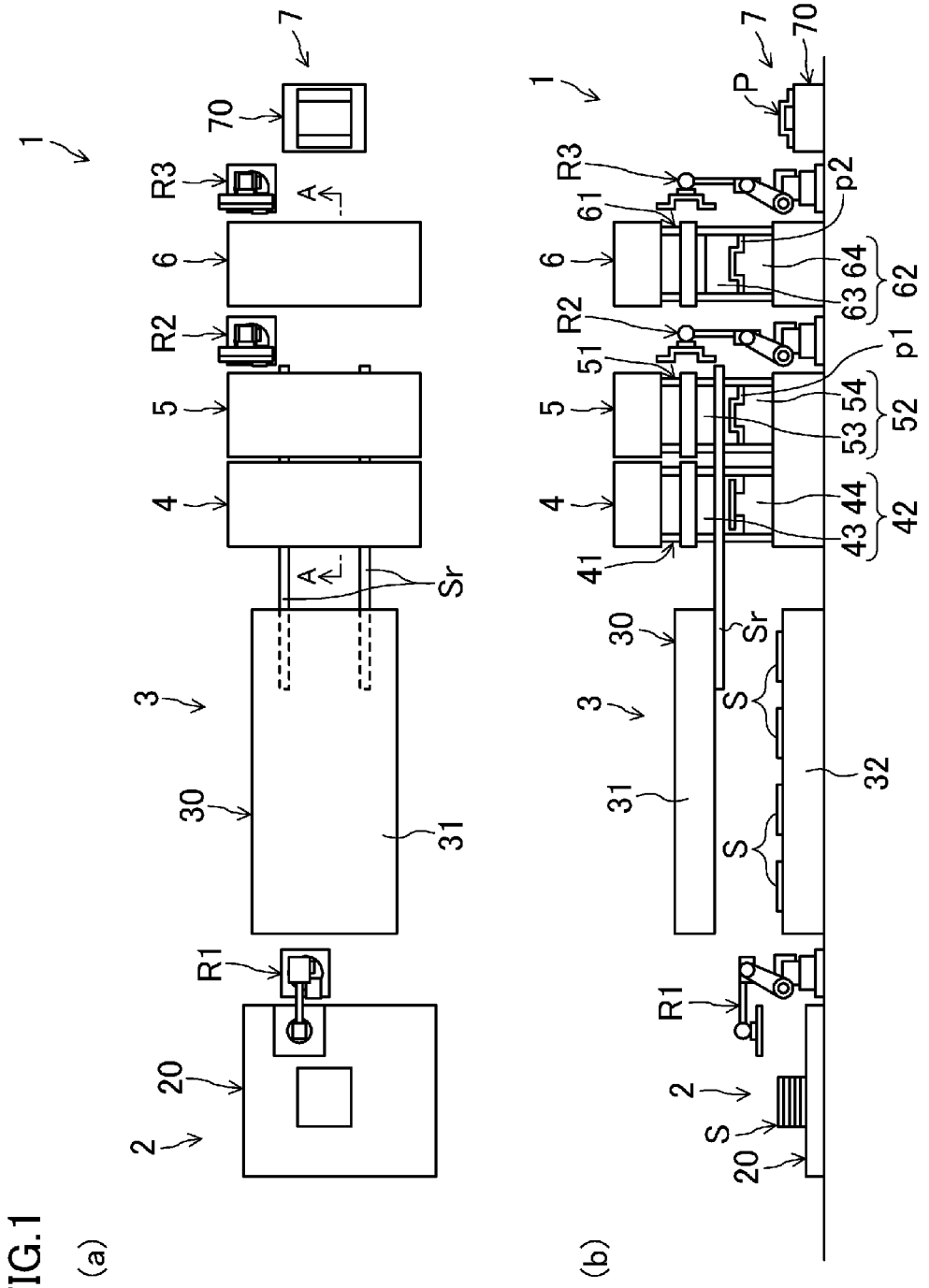

(a)
(b)
1
2
20
3
30
31
4
41
42
43
44
5
51
52
53
54
6
61
62
63
64
7
70
R1
R2
R3
A
Sr
S
P
p1
p2

FIG.1

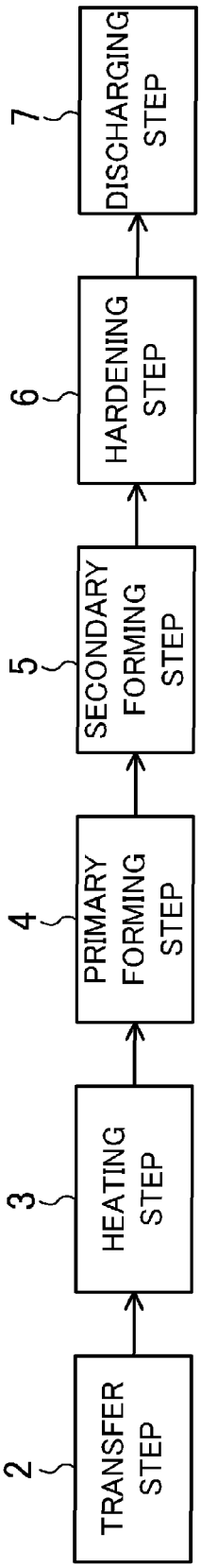
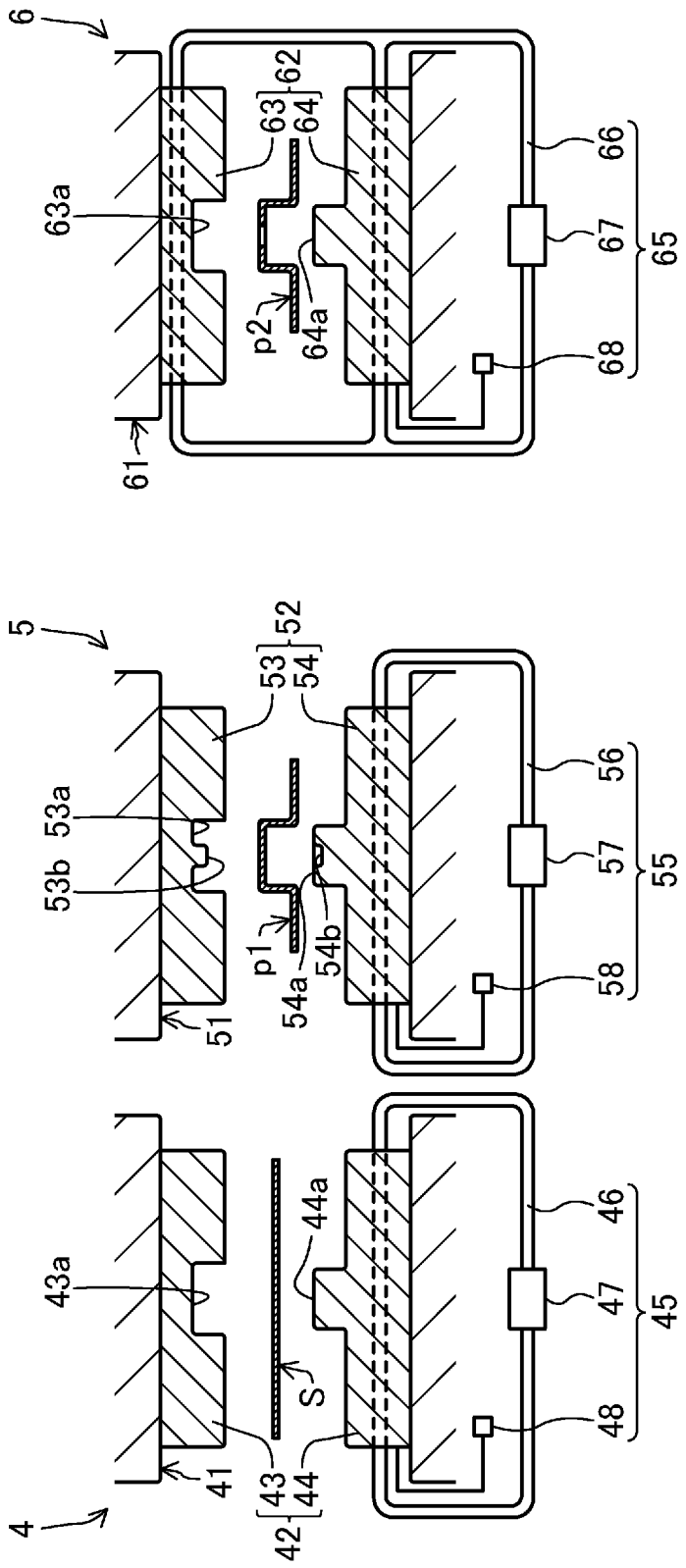

2
TRANSFER STEP
3
HEATING STEP
4
PRIMARY FORMING STEP
5
SECONDARY FORMING STEP
6
HARDENING STEP
7
DISCHARGING STEP

FIG.2

FIG.3


6
61
63a
63
64
62
64a
p2
66
67
68
65
5
51
53a
53b
53
54
52
54a
54b
p1
56
57
58
55
4
41
43a
43
44
42
44a
S
46
47
48
45

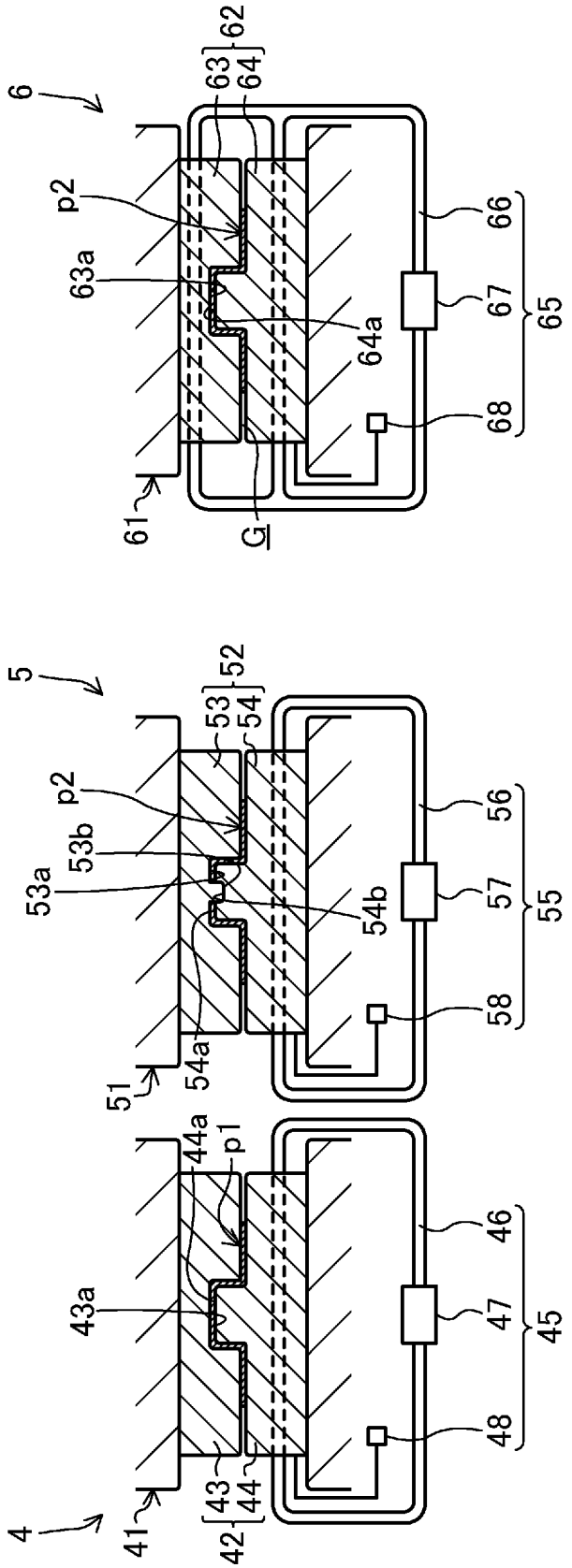

6
62
63
64
p2
63a
64a
66
67
65
68
61
G
5
52
53
54
p2
53b
53a
54b
56
57
55
58
54a
51
44a
p1
43a
46
47
45
48
43
44
42
41
4

FIG.4

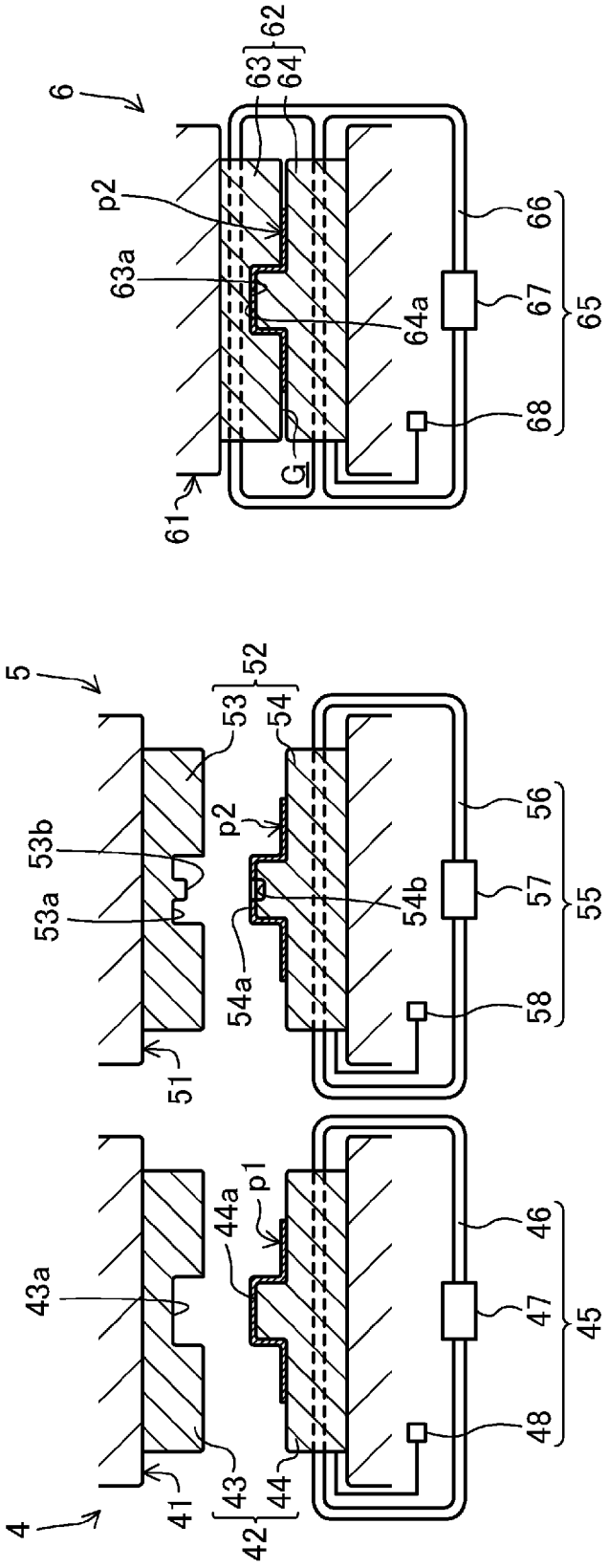

6
62
63
64
p2
63a
64a
66
67
65
68
G
61
5
52
53
54
p2
53b
53a
54b
56
57
55
54a
58
51
4
43a
44a
p1
46
47
45
48
41
43
44
42

FIG.5

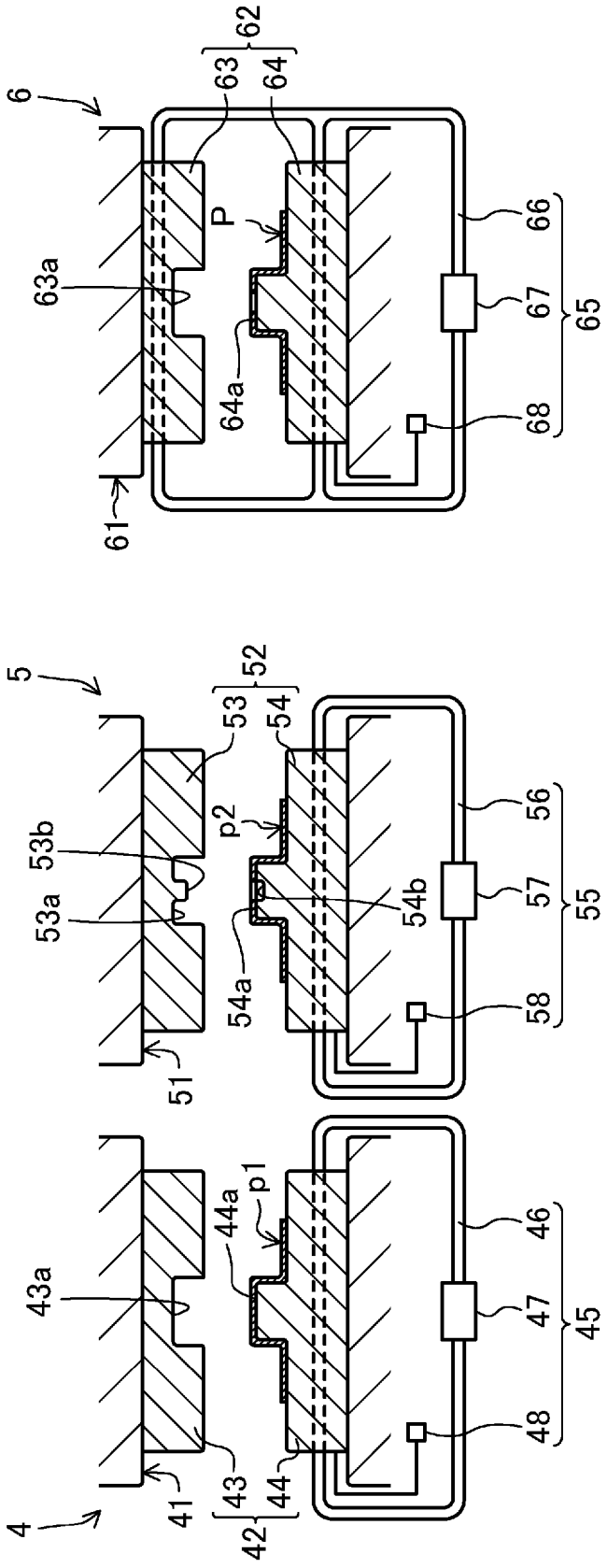

6
62
63
64
P
63a
64a
66
67
65
68
61
5
52
53
54
53b
53a
p2
54b
56
57
55
58
54a
51
4
43a
44a
p1
46
47
45
48
41
43
44
42

FIG.6

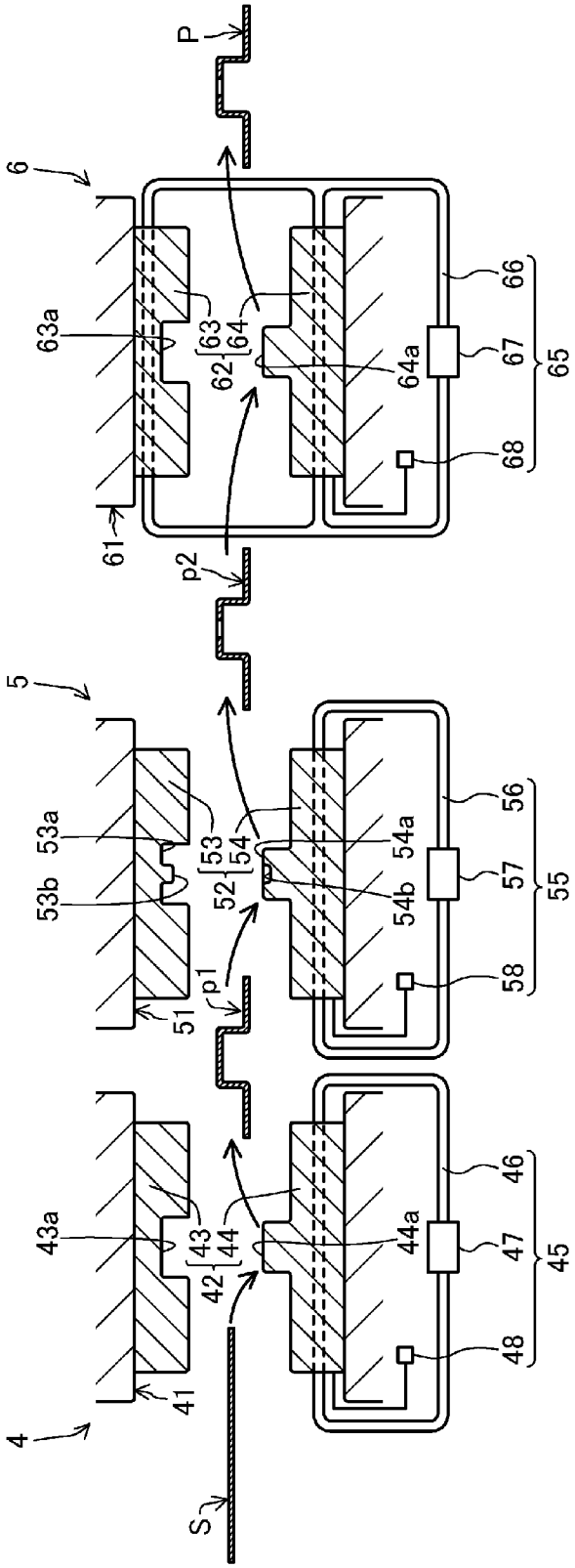

P
6
63a
63
64
62
64a
66
67
65
68
61
p2
5
53a
53b
53
54
52
54a
54b
56
57
55
58
51
p1
43a
43
44
42
44a
46
47
45
48
41
4
S

FIG.7

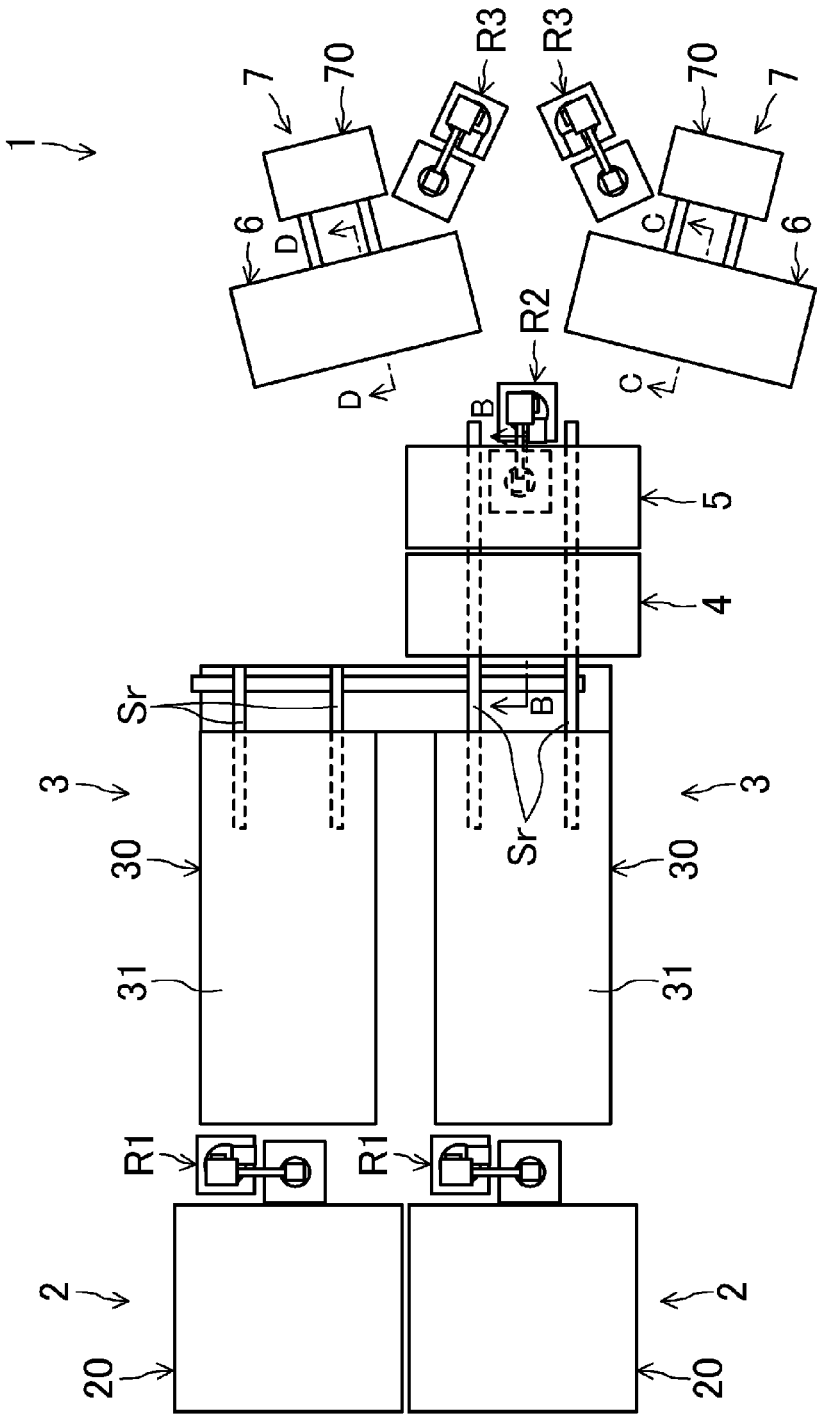


FIG.8

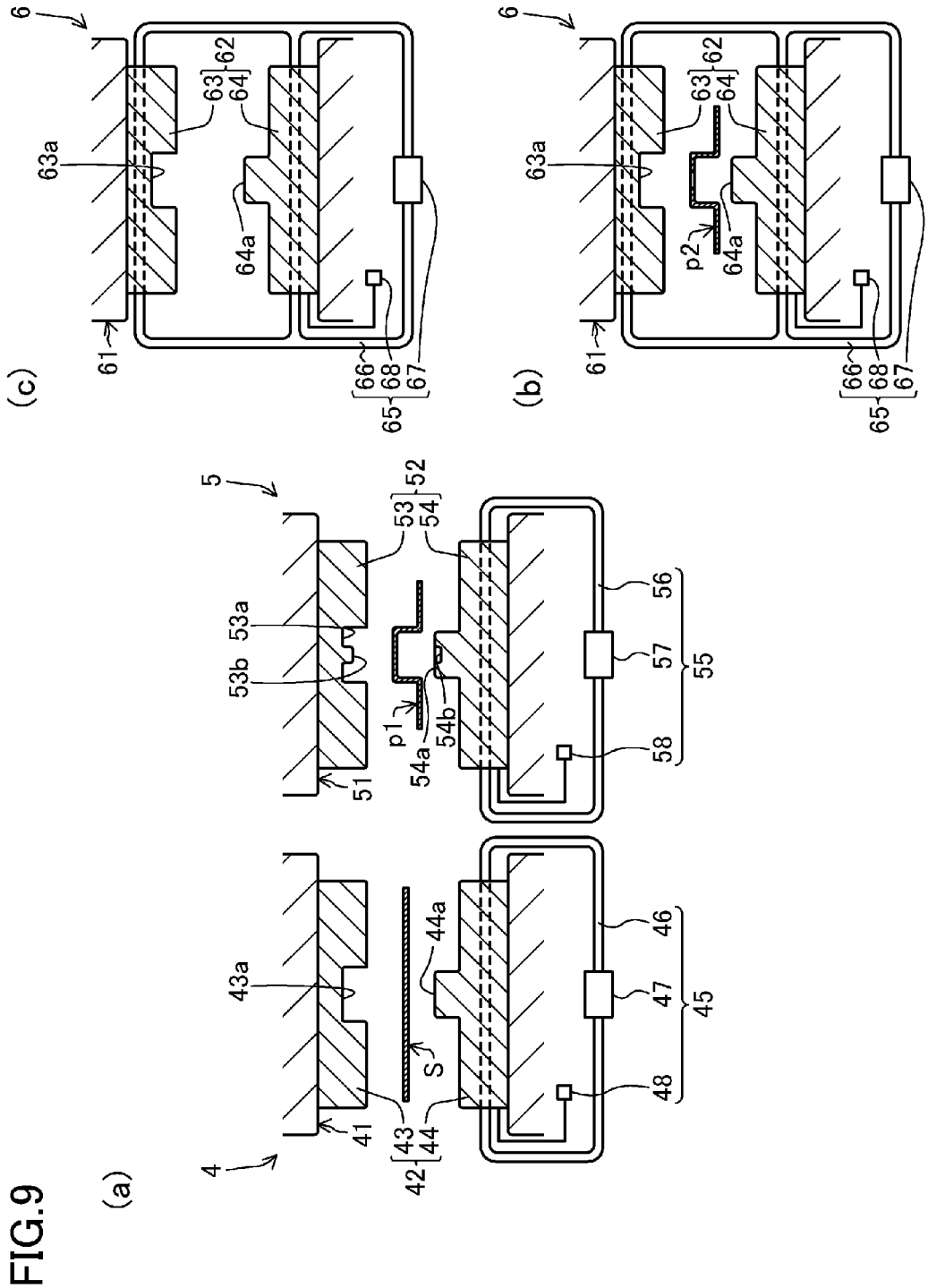
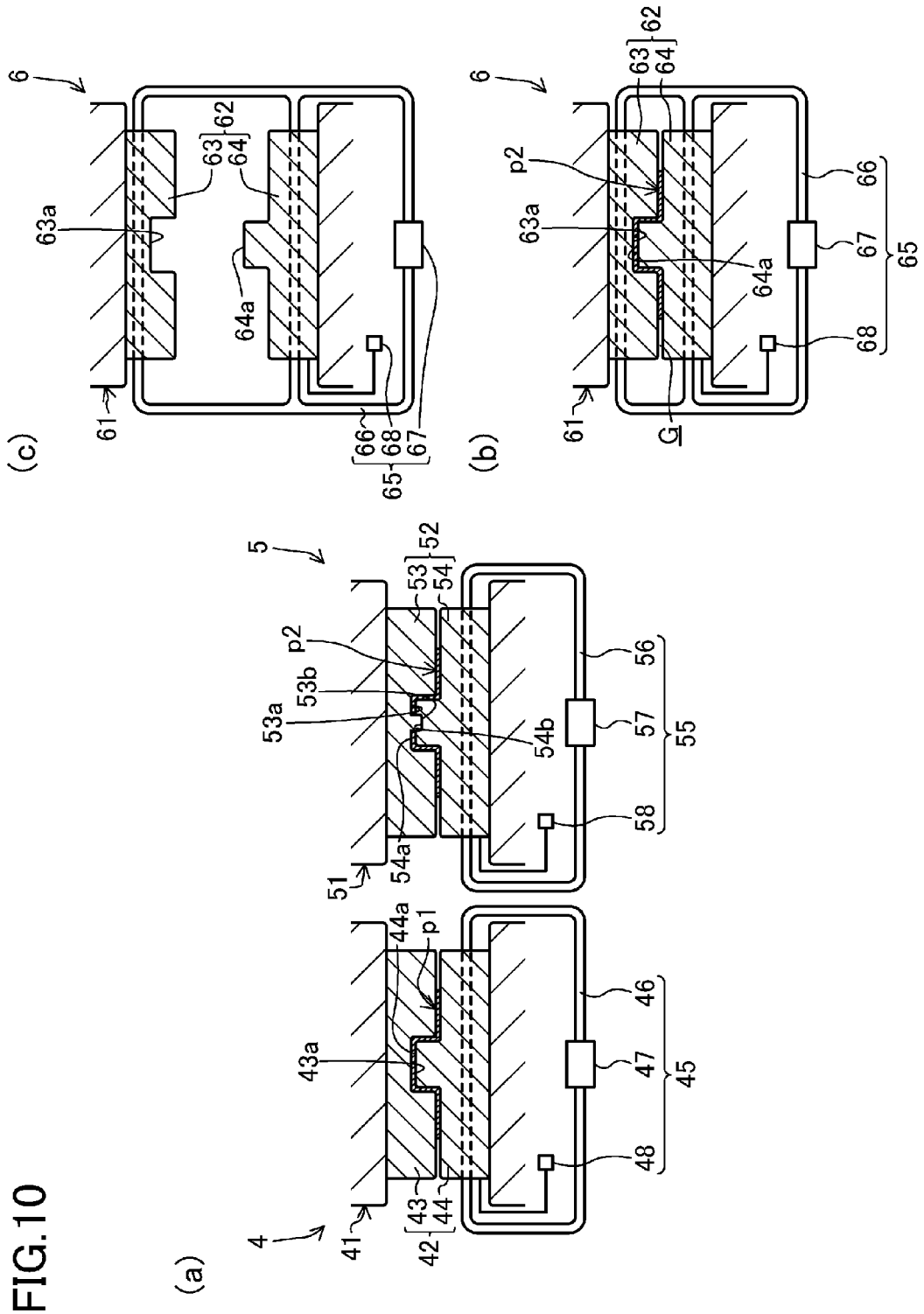

(c)
6
63a
63
64
62
64a
61
66
68
67
65
(b)
6
63a
63
64
62
p2
64a
61
66
68
67
65
(a)
5
53
54
52
53a
53b
56
57
55
p1
54a
54b
58
51
4
43a
44a
46
47
45
S
48
41
43
44
42

FIG.9

FIG.10


(a)
(b)
(c)
4
5
6
41
42
43
44
44a
p1
43a
45
46
47
48
51
52
53
54
53a
53b
p2
54a
54b
55
56
57
58
61
62
63
64
63a
64a
65
66
67
68
G

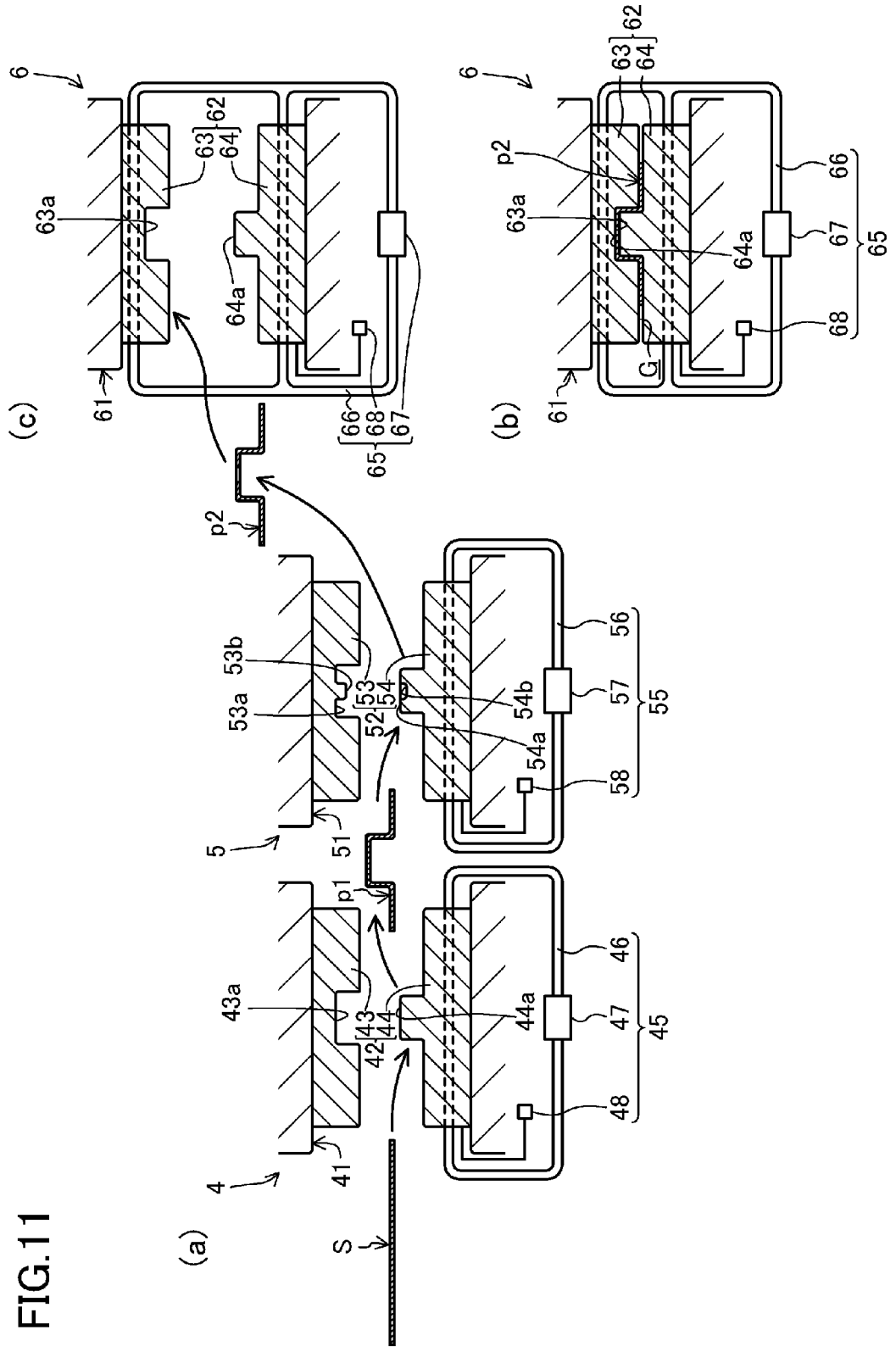

(a)
(b)
(c)
4
5
6
41
42
43
43a
44
44a
45
46
47
48
51
52
53
53a
53b
54
54a
54b
55
56
57
58
61
62
63
63a
64
64a
65
66
67
68
G
S
p1
p2

FIG.11

FIG.12

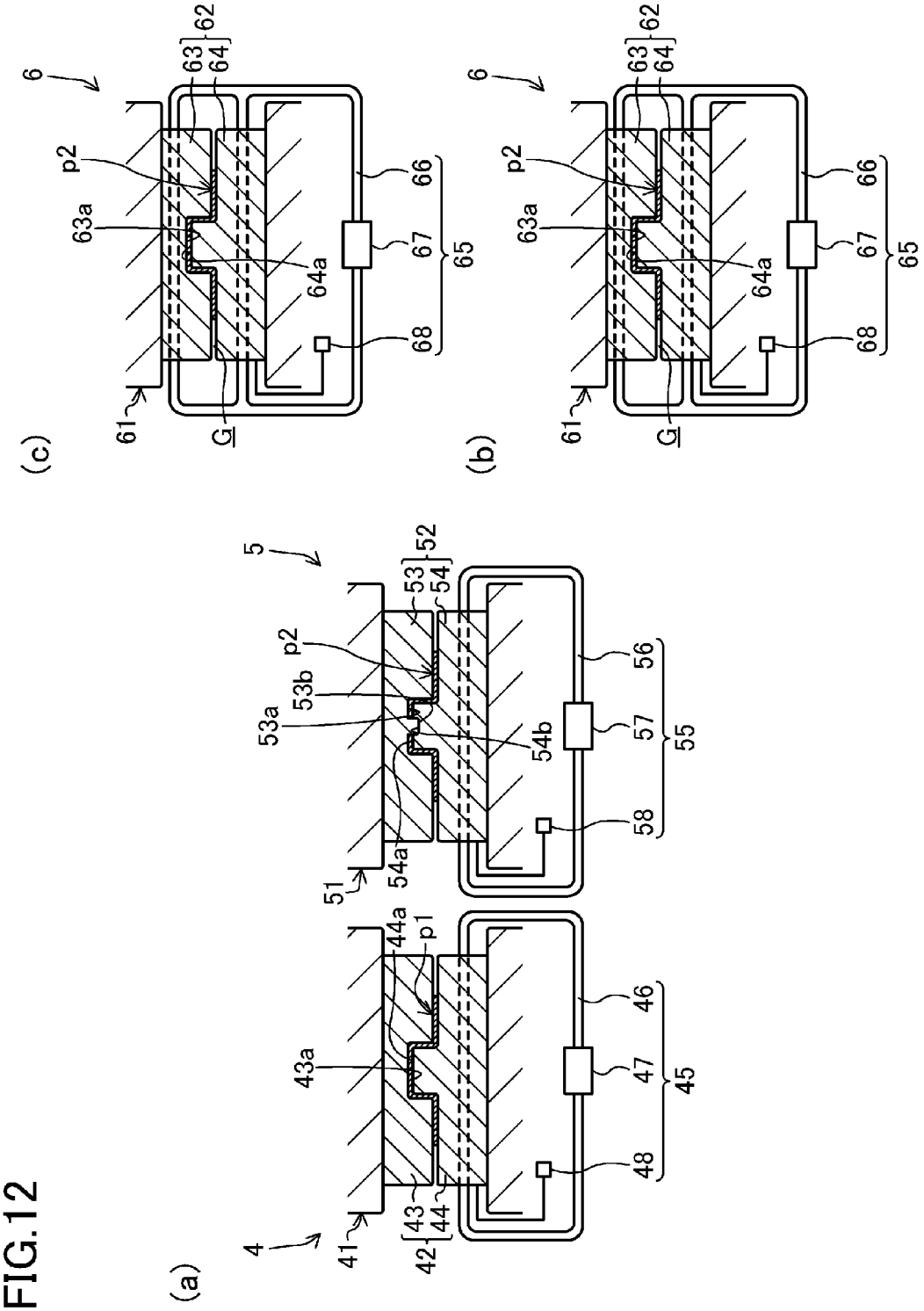

(a)
(b)
(c)
4
5
6
41
42
43
44
44a
p1
43a
45
46
47
48
51
52
53
54
p2
53b
53a
54b
54a
55
56
57
58
61
62
63
64
63a
64a
65
66
67
68
G

FIG.13

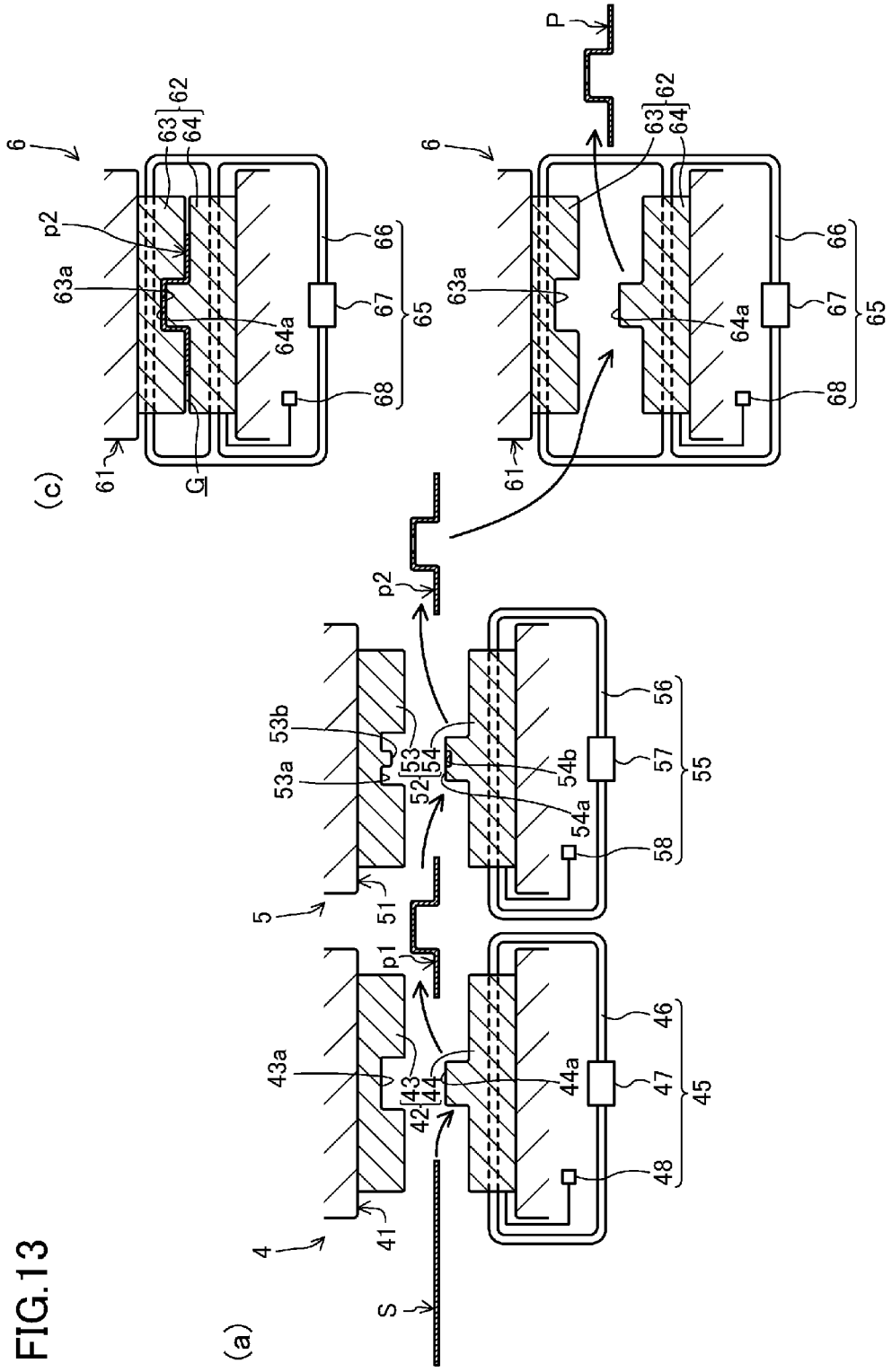
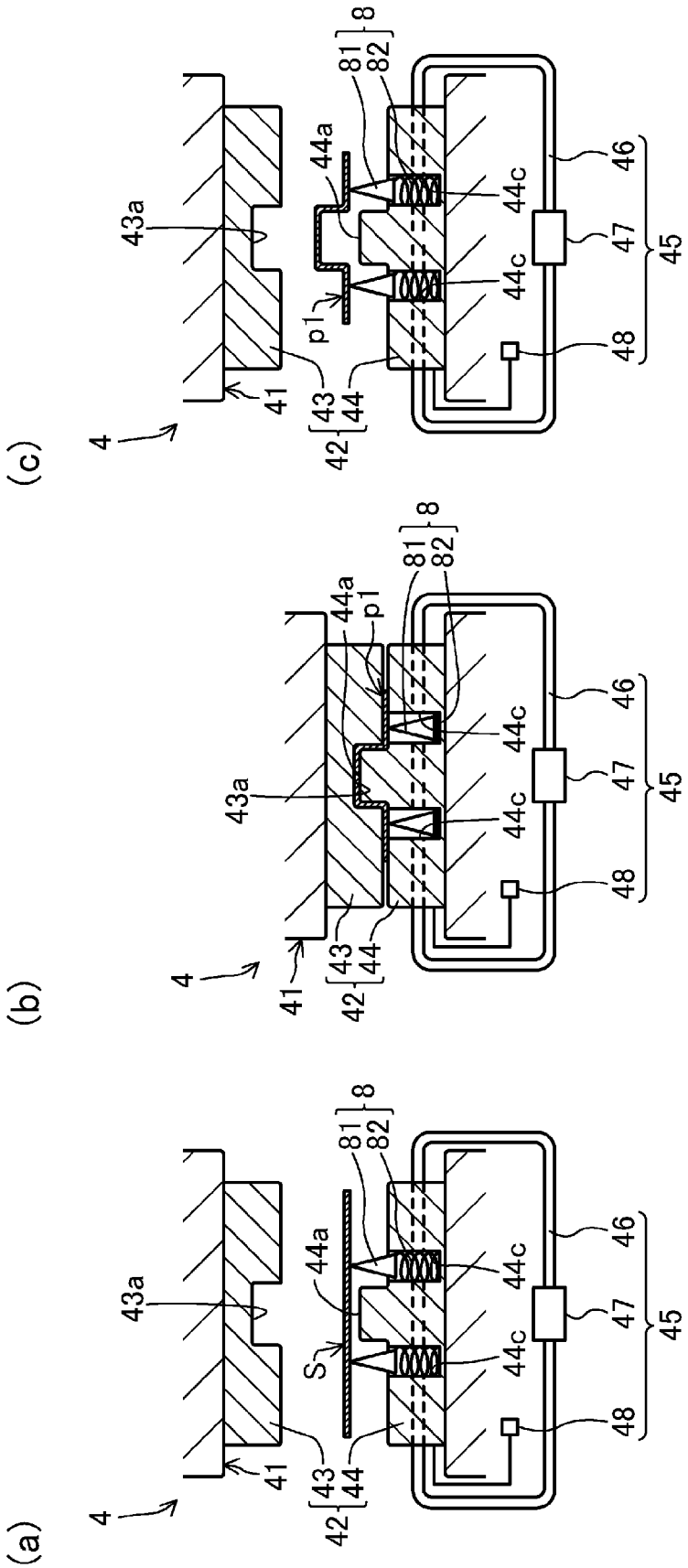

(a)
(c)
4
5
6
41
42
43
43a
44
44a
45
46
47
48
51
52
53
53a
53b
54
54a
54b
55
56
57
58
61
62
63
63a
64
64a
65
66
67
68
G
P
S
p1
p2

FIG.14



METHOD FOR FORMING STEEL SHEET BY HOT PRESSING

CROSS REFERENCE TO RELATED APPLICATIONS

This application is a national stage application, filed under 35 U.S.C. §371, of International Application No. PCT/JP2011/003537, filed Jun. 21, 2011, which claims priority to Japanese Application No. 2010-163717, filed Jul. 21, 2010, both of which are hereby incorporated by reference in their entirety.

BACKGROUND

1. Technical Field

The present invention relates to methods for forming a steel sheet by hot pressing to provide a final formed product hardened by plastically working, machining, and cooling a heated steel sheet in sequence.

2. Description of Related Art

In recent years, in the motor vehicle industry, there is a need for lightweight vehicle body structures providing a high level of safety, and in order to satisfy the need, attention has been given to a method for forming a steel sheet by hot pressing to obtain a strong vehicle body structure without increasing the sheet thickness. For example, in a method for forming a steel sheet by hot pressing according to Japanese Patent Publication No. 2005-248253 (paragraph 0022, FIG. 2), a final formed product is obtained from a steel sheet through a plurality of steps by using one die set. Specifically, a primary formed product is obtained by plastic working in which a steel sheet heated to high temperatures is pressed from above and below so as to be plastically deformed along pressing surfaces of a die set; a secondary formed product is then obtained by machining, e.g., by piercing the primary formed product; and then, the secondary formed product is cooled with the die set held at a bottom dead center position so as to be hardened, thereby obtaining a strong final formed product.

However, in the hot pressing of Japanese Patent Publication No. 2005-248253 (paragraph 0022, FIG. 2), plastic working, machining, and cooling are sequentially performed by using one die set, and thus, it takes considerable time to obtain one final formed product.

To address the problem, a method using a transfer press to increase productivity is contemplated. Specifically, a primary forming die set for primary forming in which plastic working is performed, a secondary forming die set for secondary forming in which machining is performed, a cooling die set for cooling in which cooling is performed are sequentially arranged in the transfer press so as to be synchronously operated. Steel sheets, primary formed products, and secondary formed products are sequentially fed to these die sets, thereby successively obtaining final formed products to increase productivity.

The transfer press is generally comprised of a mechanical press with high productivity. The mechanical press drives a flywheel with a motor, and the driving force of the flywheel is converted to linear motion by a crank mechanism. A clutch, a brake, etc., are provided on a power transmission path through which the driving force is transmitted, and the engagement of the clutch allows the driving force of the flywheel to be transmitted to the crank mechanism to move the die sets placed in the press up and down, and with application of the brake, the vertical movement of the die sets is stopped.

Incidentally, a cooling (hardening) step for a secondary formed product in hot pressing takes a longer time than the other two steps. Therefore, when a cooling die set is held at a bottom dead center position for a predetermined time period to cool a secondary formed product with a transfer press, the other die sets for primary forming and secondary forming are also held at corresponding bottom dead center positions for the same time period, and thus, primary and secondary formed products are held in contact with the corresponding die sets for a longer time period than necessary, thereby releasing the heat of each of the primary and secondary formed products to the corresponding die set. This release causes the temperature of the secondary formed product immediately before being carried into the cooling die set to be lower than the hardening start temperature at which hardening starts and which is required for hardening.

In order to avoid this, in a method for forming a steel sheet by hot pressing according to Japanese Patent Publication No. 2007-136533 (paragraph 0028, FIG. 1), primary and secondary formed products are heated or kept warm while being held in corresponding die sets to prevent the temperature of each of the primary and secondary formed products from being lower than the hardening start temperature.

However, in Japanese Patent Publication No. 2007-136533 (paragraph 0028, FIG. 1), a large amount of energy is consumed to manage the temperature of each of the primary and secondary formed products, and thus, the running cost, such as the electricity cost, increases.

With the use of a mechanical press for a cooling step in a transfer press, even when a brake is applied to stop a corresponding die set at a bottom dead center position, shock caused by the contact between upper and lower dies of the die set causes the stop location at which the die set stops to deviate slightly from the normal stop location corresponding to the bottom dead center position, and thus, when secondary formed products are sequentially held in the cooling die set under pressure, the conditions of contact between the secondary formed products and the cooling die set vary, and thus, the quality of final formed products may vary in continuous production.

Furthermore, while improvement in productivity is expected by simply increasing the speed of the vertical movement of the cooling die set, an increase in the operating speed of a press of the mechanical press causes the brake for stopping the vertical movement of the cooling die set to be less effective, and thus, the conditions of the contact between the secondary formed products held under pressure and the cooling die set may further vary.

It is therefore an object of the present invention to provide a method for forming a steel sheet by hot pressing which method reduces the energy consumption to a minimum to reduce the running cost, can successively provide final formed products of uniform quality, and furthermore offers high productivity.

BRIEF SUMMARY

In order to achieve the above object, a feature of the present invention is that a hydraulic press controlled by a servomotor operates a cooling die set independently without coordinating with primary and secondary forming die sets.

Specifically, according to a first aspect of the invention, a primary forming step of obtaining a primary formed product by performing plastic working in which a heated steel sheet is pressed by upper and lower dies of a primary forming die set for a predetermined time period so as to be plastically deformed along a pressing surface of each of the upper and

lower dies; a secondary forming step of carrying the primary formed product into a secondary forming die set, and machining the primary formed product with upper and lower dies of the secondary forming die set for a predetermined time period to obtain a secondary formed product; and a hardening step of carrying the secondary formed product into a cooling die set placed in a hydraulic press controlled by a servomotor, and allowing upper and lower dies of the cooling die set to hold the secondary formed product under pressure for a longer time period than the time period of each of the primary and secondary forming steps to obtain a hardened final formed product are successively performed in sequence, the hardening step is configured so as to be performed independently without coordinating with the primary and secondary forming steps, and between a start of hardening and an end of the hardening in the hardening step, the primary and secondary forming steps are both completed, the primary and secondary forming die sets are opened, the primary formed product plastically worked in the primary forming step and the secondary formed product machined in the secondary forming step are each separated from a pressing surface of at least one of the upper or lower die of a corresponding one of the die sets.

According to a second aspect of the invention, in the first aspect of the invention, the primary and secondary forming die sets may operate in synchronization with each other by using corresponding mechanical presses.

According to a third aspect of the invention, in the second aspect of the invention, the cooling die set including two cooling die sets may be prepared, while the secondary formed product is cooled with one of the cooling die sets, a secondary formed product subsequently machined with the secondary forming die set may be carried into the other cooling die set so as to be cooled, and while the secondary formed product is cooled with the other cooling die set, a hardened final formed product may be removed from the one of the cooling die sets.

According to a fourth aspect of the invention, in any one of the first through third aspects of the invention, a temperature of at least one of the primary or secondary forming die set may be adjusted by a temperature adjuster such that when the temperature of the at least one of the primary or secondary forming die set is lower than a temperature at which hardening of the secondary formed product starts, the temperature of the at least one of the primary or secondary forming die set is increased, and when the temperature of the at least one of the primary or secondary forming die set is higher than the temperature at which hardening of the secondary formed product starts, the temperature of the at least one of the primary or secondary forming die set is decreased.

According to a fifth aspect of the invention, in any one of the first through fourth aspects of the invention, between a start of hardening and an end of the hardening in the hardening step, at least one of the primary or secondary formed product may be separated from both a pressing surface of the corresponding upper die and a pressing surface of the corresponding lower die by a separator.

According to the first aspect of the invention, when the secondary formed product is held under pressure by the cooling die set, the primary formed product formed with the primary forming die set and the secondary formed product formed with the secondary forming die set are each prevented from being in contact with the pressing surface of at least one of the upper or lower die of the corresponding die set. This can avoid a situation where heat of each of the primary and secondary formed products is released to at least one of the upper or lower die of the corresponding die set to cause the temperature of the secondary formed product to be lower than the temperature at which hardening starts, thereby reducing the energy consumed by, e.g., such a heating process for keeping the temperature of each of the primary and secondary formed products high as in Japanese Patent Publication No. 2007-136533 (paragraph 0028, FIG. 1) to a minimum to reduce the running cost. Since the cooling die set is moved up and down with the hydraulic press controlled by the servomotor, the cooling die set can be stopped at a normal location even with an increase in the speed of the vertical movement of the cooling die set. Therefore, the cooling die set can be stopped at the bottom dead center position without variations to shorten the time between the carrying of the secondary formed product into the cooling die set and the removal of the final formed product to thereby increase productivity, and secondary formed products successively carried into the cooling die set press against the cooling die set without variations to provide final formed products of uniform quality.

According to the second aspect of the invention, since the mechanical presses which have been conventionally often used in plastic working and machining are used, primary and secondary formed products can be obtained without problems, and since the mechanical presses which do not require a complicated control circuit unlike the hydraulic press are used, the cost of an entire production line can be reduced.

According to the third aspect of the invention, while the secondary formed product is cooled with one of the cooling die sets, subsequent primary and secondary formed products are obtained with the primary and secondary forming die sets, respectively, thereby doubling production through the entire production line without increasing the number of primary forming die sets and the number of secondary forming die sets to achieve a compact production line providing high productivity.

According to the fourth aspect of the invention, when the temperature of each of the primary and secondary forming die sets is low at a production start time at which the outside air temperature is low, or when the temperature of each of the primary and secondary forming die sets is increased due to the frictional heat generated in continuous production, the temperature of each of the primary and secondary forming die sets can be adjusted to the temperature at which hardening starts, thereby reducing variations among the temperatures of secondary formed products carried into the cooling die set. This enables the hardening of the final formed products in the cooling die set without variations, and can provide final formed products of uniform quality.

According to the fifth aspect of the invention, when the secondary formed product is held under pressure by the cooling die set, the primary formed product obtained with the primary forming die set and the secondary formed product obtained with the secondary forming die set are each never in contact with both the pressing surface of the upper die of the corresponding die set and the pressing surface of the lower die thereof. This ensures the prevention of the heat release from both of the pressing surface of the upper die and the pressing surface of the lower die, and avoids a situation where the temperature of the secondary formed product becomes lower than the temperature at which hardening starts, thereby further reducing the energy consumed by, e.g., such a heating process for keeping the temperature of each of the primary and secondary formed products high as in Japanese Patent Publication No. 2007-136533 (paragraph 0028, FIG. 1) to reduce the running cost.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. **1**(*a*) and **1**(*b*) illustrate the layout of a production line to which a forming method according to a first embodi-

ment of the present invention is applied, in which FIG. **1**(*a*) is a plan view of the production line, and FIG. **1**(*b*) is a side view thereof.

FIG. **2** is a block diagram of the production line to which the forming method according to the first embodiment of the present invention is applied.

FIG. **3** is a cross-sectional view taken along the line A-A in FIG. **1**(*a*), and illustrates a situation where a steel sheet, a primary formed product, and a secondary formed product are carried into a primary forming die set, a secondary forming die set, and a cooling die set, respectively, each having an upper die which has moved up.

FIG. **4** illustrates a situation where the upper dies of the primary forming die set, the secondary forming die set, and the cooling die set are moved downward from their positions in FIG. **3** to plastically work the steel sheet with the primary forming die set, machine the primary formed product with the secondary forming die set, and cool (harden) the secondary formed product with the cooling die set.

FIG. **5** illustrates a situation where while the upper dies of the primary and secondary forming die sets move upward from their positions in FIG. **4** so that primary and secondary formed products are separated from pressing surfaces of the corresponding die sets, the secondary formed product is cooled (hardened) with the cooling die set.

FIG. **6** illustrates a situation where the upper die of the cooling die set moves upward from its position in FIG. **5**, and a final formed product is obtained.

FIG. **7** illustrates a situation where the situation in FIG. **6** is changed so that the final formed product is removed from the cooling die set, the secondary formed product is removed from the secondary forming die set and carried into the cooling die set, the primary formed product is removed from the primary forming die set and carried into the secondary forming die set, and a steel sheet is carried into the primary forming die set.

FIG. **8** is a diagram corresponding to FIG. **1**(*a*) according to a second embodiment of the present invention.

FIG. **9**(*a*) is a cross-sectional view taken along the line B-B in FIG. **8**, FIG. **9**(*b*) is a cross-sectional view taken along the line C-C in FIG. **8**, FIG. **9**(*c*) is a cross-sectional view taken along the line D-D in FIG. **8**, and FIGS. **9**(*a*)-**9**(*c*) illustrate a situation where a steel sheet, a primary formed product, and a secondary formed product are carried into a primary forming die set, a secondary forming die set, and one of cooling die sets, respectively, each having an upper die which has moved up.

FIGS. **10**(*a*)-**10**(*c*) illustrate a situation where the upper dies of the primary forming die set, the secondary forming die set, and the one of the cooling die sets are moved downward from their positions in FIG. **9** to plastically work the steel sheet with the primary forming die set, machine the primary formed product with the secondary forming die set, and cool (harden) the secondary formed product with the one of the cooling die sets.

FIGS. **11**(*a*)-**11**(*c*) illustrate a situation where while the upper dies of the primary and secondary forming die sets move upward from their positions in FIG. **10**(*a*) so that primary and secondary formed products are separated from pressing surfaces of the corresponding die sets, the secondary formed product is removed from the secondary forming die set and carried into the other cooling die set, the primary formed product is removed from the primary forming die set and carried into the secondary forming die set, and a steel sheet is carried into the primary forming die set, the secondary formed product is cooled (hardened) with the one of the cooling die sets.

FIGS. **12**(*a*)-**12**(*c*) illustrate a situation where the upper dies of the primary forming die set, the secondary forming die set, and the other cooling die set are moved downward from their positions in FIGS. **11**(*a*) and **11**(*c*) to plastically work the steel sheet with the primary forming die set, machine the primary formed product with the secondary forming die set, and cool (harden) the secondary formed product with the other cooling die set.

FIGS. **13**(*a*)-**13**(*c*) illustrate a situation where the upper dies of the primary forming die set, the secondary forming die set, and the one of the cooling die sets move upward from their positions in FIGS. **12**(*a*) and **12**(*b*), a final formed product is removed from the one of the cooling die sets, the secondary formed product is removed from the secondary forming die set and carried into the one of the cooling die sets, the primary formed product is removed from the primary forming die set and carried into the secondary forming die set, and a steel sheet is carried into the primary forming die set.

FIG. **14**(*a*) is a diagram corresponding to a portion of FIG. **3**, and illustrating only a primary forming die set for use in a forming method according to a third embodiment of the present invention, FIG. **14**(*b*) illustrates a situation where an upper die of the primary forming die set is moved downward from its position in FIG. **14**(*a*) to plastically work a steel sheet, and FIG. **14**(*c*) illustrates a situation where the upper die of the primary forming die set moves upward from its position in FIG. **14**(*b*) so that a primary formed product is separated from pressing surfaces of both of the upper die and a lower die of the primary forming die set.

DETAILED DESCRIPTION

Embodiments of the present invention will be described hereinafter in detail with reference to the drawings. The following preferred embodiments are merely examples in nature.

FIGS. **1**(*a*) and **1**(*b*) illustrate a production line **1** according to a first embodiment of the present invention. The production line **1** is configured to form steel sheets S by hot pressing, and as illustrated in FIG. **2**, a section of the production line **1** implementing a carrying step **2** in which steel sheets S before being formed are stored, a section thereof implementing a heating step **3** in which steel sheets S carried from the section implementing the carrying step **2** are heated, a section thereof implementing a primary forming step **4** in which plastic working of each of the steel sheets S heated in the heating step **3** is performed for a predetermined time period, a section thereof implementing a secondary forming step **5** in which a primary formed product p**1** formed in the primary forming step **4** is machined, e.g., pierced, for a predetermined time period, a section thereof implementing a hardening step **6** in which a secondary formed product p**2** formed by being machined in the secondary forming step **5** is held under pressure so as to be hardened, and a section thereof implementing a discharging step **7** in which a final formed product P hardened in the hardening step **6** is removed from the section implementing the hardening step **6** and stored are arranged on a substantially straight line sequentially from the upstream side of the production line **1**. The above-described term "plastic working" denotes processes, such as draw forming, crash forming, and bend forming. In the secondary forming step **5**, when machining, such as piercing, is performed, bending, etc., may be performed to some extent.

The section implementing the carrying step **2** includes a first pallet **20** on which a plurality of steel sheets S cut into an appropriate shape in an unshown cutting step are placed one on another. A first robot R**1** which is an industrial robot is

disposed between the section implementing the carrying step **2** and the section implementing the heating step **3**, and the first robot R**1** sequentially carries the steel sheets S stacked on the first pallet **20** into the section implementing the heating step **3**.

The section implementing the heating step **3** includes a heating furnace **30** extending from the upstream side of the production line **1** to the downstream side thereof, and heating the steel sheets S. The heating furnace **30** includes a lower furnace body **32** which is a lower portion of the heating furnace **30**, and an upper furnace body **31** which is an upper portion of the heating furnace **30** opposed to the lower furnace body **32**, and although not shown, the lower furnace body **32** includes a plurality of rollers rotationally driven by a motor, and a heater configured to increase the temperature of atmospheric gas between the upper furnace body **31** and the lower furnace body **32**. The steel sheets S carried into the upstream side of the heating furnace **30** by the first robot R**1** are carried to the downstream side of the production line **1** through the plurality of rollers in the heating furnace **30**, and during the time period during which the steel sheets S are carried to the downstream side, the temperatures of the steel sheets S are increased to temperatures of about 800-1000° C. with the atmospheric gas the temperature of which is increased by the heater.

Two transfer rails Sr are laid between the section implementing the heating step **3** and the section implementing the secondary forming step **5** to pass through the section implementing the primary forming step **4**, and two unshown automatic conveyors are movably placed on the transfer rails Sr. The automatic conveyors are used to carry the steel sheets S heated in the heating furnace **30** into the section implementing the primary forming step **4**, and simultaneously carry the primary formed product p**1** plastically worked in the primary forming step **4** into the section implementing the secondary forming step **5**.

The section implementing the primary forming step **4** includes a mechanical press **41**, and a primary forming die set **42** configured to perform plastic working in which a steel sheet S is pressed from above and below so as to be plastically deformed is placed in the mechanical press **41**. As illustrated in FIGS. **3-6**, the mechanical press **41** is configured to move an upper die **43** of the primary forming die set **42** upward from a lower die **44** thereof and downward to the lower die **44**.

The lower die **44** has a lower pressing surface **44***a* having a generally protruding portion when viewed in cross section, and the upper die **43** has an upper pressing surface **43***a* having a generally depressed portion when viewed in cross section, and corresponding to the lower pressing surface **44***a* of the lower die **44**. When one of the heated steel sheets S is placed on the lower pressing surface **44***a* of the lower die **44**, and the upper die **43** is moved down to a bottom dead center position, the steel sheet S is plastically worked to obtain a primary formed product p**1** having a cross section forming a generally hat-like shape.

As illustrated in FIGS. **3-6**, a pipe **46** is disposed inside the lower die **44** of the primary forming die set **42**, and a driver **47** configured to circulate a heating medium, such as hot water, between the lower die **44** and a storage tank outside the drawings is connected to the pipe **46**. A temperature sensor **48** is connected to the primary forming die set **42**. A temperature adjuster **45** of the present invention includes the pipe **46**, the driver **47**, and the temperature sensor **48**, the temperature sensor **48** detects the temperature of the primary forming die set **42**, and the temperature of the heating medium circulating through the pipe **46** is adjusted such that when the temperature of the primary forming die set **42** is lower than the temperature at which a secondary formed product p**2** is hardened (about 650° C.), the temperature of the primary forming die set **42** is increased, and when the temperature of the primary forming die set **42** is higher than the temperature at which the secondary formed product p**2** is hardened, the temperature of the primary forming die set **42** is decreased.

The section implementing the secondary forming step **5** includes a mechanical press **51**, and a secondary forming die set **52** configured to pierce the primary formed product p**1** is placed in the mechanical press **51**. As illustrated in FIGS. **3-6**, the drive source of the mechanical press **51** is in synchronization with the drive source of the mechanical press **41**, and the primary and secondary forming die sets **42** and **52** operate in synchronization with each other.

The lower die **54** has a lower pressing surface **54***a* having a generally protruding portion when viewed in cross section, and corresponding to the shape of the back surface of the primary formed product p**1**, and a piercing hole **54***b* for piercing is formed in the top part of the lower pressing surface **54***a*. The upper die **53** has an upper pressing surface **53***a* having a generally depressed portion when viewed in cross section, and corresponding to the shape of the front surface of the primary formed product p**1**, and the upper pressing surface **53***a* includes a piercing protrusion **53***b* corresponding to the piercing hole **54***b*. When the primary formed product p**1** is placed on the lower pressing surface **54***a* of the lower die **54** with the back surface of the primary formed product p**1** facing toward the lower die **54**, the back surface of the primary formed product p**1** is along the lower pressing surface **54***a*. When, in this situation, the upper die **53** is moved down to the bottom dead center position, the primary formed product p**1** is pierced with the piercing hole **54***b* and the piercing protrusion **53***b* to obtain a secondary formed product p**2**.

As illustrated in FIGS. **3-6**, a pipe **56** is disposed inside the lower die **54** of the secondary forming die set **52**, and a driver **57** configured to circulate a heating medium, such as hot water, between the lower die **54** and a storage tank outside the drawings is connected to the pipe **56**. A temperature sensor **58** is connected to the secondary forming die set **52**. The temperature adjuster **55** of the present invention includes the pipe **56**, the driver **57**, and the temperature sensor **58**, the temperature sensor **58** detects the temperature of the secondary forming die set **52**, and the temperature of the heating medium circulating through the pipe **56** is adjusted such that when the temperature of the secondary forming die set **52** is lower than the temperature at which the secondary formed product p**2** is hardened, the temperature of the secondary forming die set **52** is increased, and when the temperature of the secondary forming die set **52** is higher than the temperature at which the secondary formed product p**2** is hardened, the temperature of the secondary forming die set **52** is decreased.

A second robot R**2** which is an industrial robot is disposed between the section implementing the secondary forming step **5** and the section implementing the hardening step **6**, and the second robot R**2** sequentially carries secondary formed products p**2** formed in the secondary forming step **5** into the section implementing the hardening step **6**.

The section implementing the hardening step **6** includes a hydraulic press **61**, and a cooling die set **62** for cooling is placed in the hydraulic press **61**. The hardening step **6** is configured so as to be performed independently without coordinating with the primary and secondary forming steps **4** and **5**, the hydraulic press **61** operates under the control of a servomotor, and an upper die **63** of the cooling die set **62** is moved upward from a lower die **64** thereof and downward to the lower die **64**.

The lower die **64** has a lower pressing surface **64***a* having a generally protruding portion when viewed in cross section,

and corresponding to the shape of the back surface of the secondary formed product p2, and when the secondary formed product p2 is placed on the lower pressing surface **64***a* of the lower die **64** with the back surface of the secondary formed product p2 facing toward the lower die **64**, the back surface of the secondary formed product p2 is along the lower pressing surface **64***a*. The upper die **63** has an upper pressing surface **63***a* having a generally depressed portion when viewed in cross section, and corresponding to the shape of the front surface of the secondary formed product p2. The size of a gap G formed between the upper pressing surface **63***a* and the lower pressing surface **64***a* with the upper die **63** of the cooling die set **62** moved down to the bottom dead center position is set at a size slightly smaller than the thickness of the secondary formed product p2. Therefore, when the upper die **63** is moved down with the secondary formed product p2 placed on the lower die **64**, the cooling die set **62** presses against the front and back surfaces of the secondary formed product p2.

As illustrated in FIGS. **3-6**, a pipe **66** is disposed inside the upper and lower dies **63** and **64**, and a driver **67** configured to circulate cold water between each of the upper and lower dies **63** and **64** and a storage tank outside the drawings is connected to the pipe **66**. A temperature sensor **68** is connected to the cooling die set **62**. A cooler **65** of the present invention includes the pipe **66**, the driver **67**, and the temperature sensor **68**, the temperature sensor **68** detects the temperature of the cooling die set **62**, and the temperature of the cold water circulating through the pipe **66** is adjusted such that when the temperature of the cold water is higher than the set temperature of the cold water for hardening, the temperature of the cold water is decreased.

A third robot R**3** which is an industrial robot is disposed between the section implementing the hardening step **6** and the section implementing the discharging step **7**, and final formed products P formed in the hardening step **6** are sequentially removed from the section implementing the hardening step **6** and carried into the section implementing the discharging step **7** by the third robot R**3**.

The section implementing the discharging step **7** includes a second pallet **70** on which a final formed product P formed in the hardening step **6** is placed, and a plurality of final formed products P sequentially formed in the hardening step **6** can be stacked on the second pallet **70**.

Next, a method for manufacturing a final formed product P from a steel sheet S by hot pressing along the production line **1** will be described.

FIG. **3** illustrates a situation where a steel sheet S heated in a heating furnace **30**, a primary formed product p**1** formed with a primary forming die set **42**, and a secondary formed product p2 formed with a secondary forming die set **52** are carried into the primary forming die set **42**, the secondary forming die set **52**, and a cooling die set **62**, respectively.

First, as illustrated in FIG. **4**, an upper die **43** of the primary forming die set **42** and an upper die **53** of the secondary forming die set **52** are moved down from their positions illustrated in FIG. **3** in synchronization with each other, and an upper die **63** of the cooling die set **62** also moves down at the same time as the upper dies **43** and **53**. A primary formed product p**1** is formed from the steel sheet S with the primary forming die set **42**, a secondary formed product p2 is formed from the primary formed product p**1** with the secondary forming die set **52**, and the hardening of the secondary formed product p2 is started with the secondary formed product p2 held under pressure by the cooling die set **62**.

Next, as illustrated in FIG. **5**, while the secondary formed product p2 is hardened with the upper die **63** of the cooling die set **62** moved down, the upper die **43** of the primary forming die set **42** and the upper die **53** of the secondary forming die set **52** move up in synchronization with each other without coordinating with the cooling die set **62**; the primary formed product p**1** plastically worked in the primary forming step **4** is separated from an upper pressing surface **43***a* of the upper die **43** while being in contact with a lower pressing surface **44***a* of the lower die **44**; and the secondary formed product p2 pierced in the secondary forming step **5** is separated from an upper pressing surface **53***a* of the upper die **53** while being in contact with a lower pressing surface **54***a* of the lower die **54**. Therefore, when the secondary formed product p2 is held under pressure by the cooling die set **62**, the contact between the primary formed product p**1** formed with the primary forming die set **42** and the upper pressing surface **43***a* of the upper die **43** can be prevented, and the contact between the secondary formed product p2 formed with the secondary forming die set **52** and the upper pressing surface **53***a* of the upper die **53** can be prevented. This can avoid a situation where the heat of the primary formed product p**1** and the heat of the secondary formed product p2 are released to the upper pressing surface **43***a* of the upper die **43** and the upper pressing surface **53***a* of the upper die **53**, respectively, to cause the temperature of the secondary formed product p2 to be lower than the temperature at which the secondary formed product p2 is hardened, thereby reducing the energy consumed by, e.g., such a heating process for keeping the temperature of each of the primary and secondary formed products p**1** and p2 high as in Japanese Patent Publication No. 2007-136533 (paragraph 0028, FIG. 1) to a minimum to reduce the running cost.

Also when the die sets are configured such that the primary formed product p**1** plastically worked in the primary forming step **4** and the secondary formed product p2 pierced in the secondary forming step **5** are in contact with the upper pressing surfaces **43***a* and **53***a* of the upper dies **43** and **53**, respectively, and are separated from the lower pressing surfaces **44***a* and **54***a* of the lower dies **44** and **54**, respectively, with the die sets opened, advantages similar to the above advantages can be provided.

Next, after a lapse of a predetermined time period from the time when the situation in FIG. **5** starts, hardening is finished in the cooling die set **62** to obtain a final formed product P, and as illustrated in FIG. **6**, the upper die **63** of the cooling die set **62** moves up. Subsequently, the final formed product P is removed from the cooling die set **62** by the third robot R**3**, the secondary formed product p2 is removed from the secondary forming die set **52** and carried into the cooling die set **62** by the second robot R**2**, the primary formed product p**1** is simultaneously removed from the primary forming die set **42** and carried into the secondary forming die set **52** by an automatic conveyor (not shown), and the steel sheet S is then removed from the heating furnace **30** and carried into the primary forming die set **42** by an automatic conveyor (not shown). As such, a primary forming step **4**, a secondary forming step **5**, and a hardening step **6** are successively performed in sequence, thereby obtaining final formed products P on the production line.

When the final formed products P are to be successively obtained, the temperature adjusters **45** and **55** each adjust the temperature of a heating medium circulating through a corresponding one of the pipes **46** and **56** such that when the temperature of a corresponding one of the primary and secondary forming die sets **42** and **52** is low at a production start time at which the outside air temperature is low, the temperature thereof is increased, and when the temperature of a corresponding one of the primary and secondary forming die

sets **42** and **52** is increased due to the frictional heat generated in the continuous production, the temperature thereof is decreased. Therefore, the temperatures of the primary and secondary forming die sets **42** and **52** can be adjusted to the temperature at which hardening is started by the temperature adjusters **45** and **55**, thereby reducing variations among the temperatures of secondary formed products p**2** carried into the cooling die set **62**. This enables the hardening of final formed products P in the cooling die set **62** without variations, and can provide final formed products P of uniform quality.

In view of the above, according to the first embodiment of the present invention, since the cooling die set **62** is moved up and down by the hydraulic press **61** controlled by the servomotor, the cooling die set **62** can be stopped at a normal location even with an increase in the speed of the vertical movement of the cooling die set **62**. Therefore, the cooling die set **62** can be stopped at the bottom dead center position without variations to shorten the time between the carrying of the secondary formed product p**2** into the cooling die set **62** and the removal of the final formed product P to thereby increase productivity, and secondary formed products p**2** successively carried into the cooling die set **62** press against the cooling die set **62** without variations to provide final formed products P of uniform quality.

Furthermore, since the mechanical presses **41** and **51** which have been conventionally often used in plastic working and machining are used, primary formed products p**1** and secondary formed products p**2** can be obtained without problems, and since the mechanical presses **41** and **51** which do not require a complicated control circuit unlike the hydraulic press **61** are used, the cost of the entire production line **1** can be reduced.

Although, in the first embodiment, a heating medium, such as hot water, is used to heat the primary and secondary forming die sets **42** and **52**, the heating medium does not necessarily need to be used, and the die sets may be heated, for example, by electrical heat generation.

Although the mechanical presses **41** and **51** are used in the primary and secondary forming steps **4** and **5**, hydraulic presses may be used to obtain primary and secondary formed products p**1** and p**2**.

Although, in the primary and secondary forming steps **4** and **5**, the vertical movement of the upper die **43** of the primary forming die set **42** is in synchronization with that of the upper die **53** of the secondary forming die set **52**, the vertical movement of the upper die **43** may be prevented from being in synchronization with that of the upper die **53**.

Although, in the heating furnace **30** of this embodiment, the steel sheets S are heated by increasing the temperature of the atmospheric gas to high temperatures, a heating process is not limited to the above process, and a heating process using, e.g., induction heating may be used.

Although automatic conveyors (not shown) are used to carry the primary formed product p**1** from the section implementing the primary forming step **4** into the section implementing the secondary forming step **5** and carry the steel sheet S from the section implementing the heating step **3** into the section implementing the primary forming step **4**, industrial robots may be used to carry such products into the corresponding sections.

Although, in the first embodiment, the pipes **46** and **56** are disposed only in the lower dies **44** and **54** of the primary and secondary forming die sets **42** and **52**, respectively, to adjust the temperatures of the die sets, the pipes **46** and **56** may be disposed in the upper dies **43** and **53**, respectively, to adjust the temperatures of the die sets.

Although the primary and secondary forming die sets **42** and **52** include the temperature adjusters **45** and **55**, respectively, the temperature of at least one of the primary and secondary forming die sets **42** and **52** may be adjusted.

FIG. **8** illustrates a production line **1** according to a second embodiment of the present invention. Unlike the first embodiment, the production line **1** of the second embodiment includes two sections which each implement a carrying step **2** and are arranged in parallel, two sections which each implement a heating step **3** and are arranged in parallel, two sections which each implement a hardening step **6** and are arranged in parallel, and two sections which each implement a discharging step **7** and are arranged in parallel, and the other elements are identical with those of the first embodiment; thus, the difference between the first and second embodiments will be described in detail.

A first robot R**1** is disposed between each of the sections implementing the carrying step **2** and one of the sections implementing the heating step **3**, which is placed in parallel with the section implementing the carrying step **2**, and a third robot R**3** is disposed between each of the sections implementing the hardening step **6** and one of the sections implementing the discharging step **7**, which is placed in parallel with the section implementing the hardening step **6**. Each of the two sections implementing the heating section **3** is connected to the section implementing the primary forming step **4** through transfer rails Sr extending from the section implementing the heating step **3** to the section implementing the primary forming step **4**, thereby sequentially carrying steel sheets S heated in the heating step **3** into the section implementing the primary forming step **4**.

Next, a method for manufacturing a final formed product P from a steel sheet S by hot pressing along the production line **1** of the second embodiment will be described.

FIGS. **9**(*a*)-**9**(*c*) illustrate a situation where a steel sheet S heated in a heating furnace **30**, a primary formed product p**1** formed with a primary forming die set **42**, and a secondary formed product p**2** formed with a secondary forming die set **52** are carried into the primary forming die set **42**, the secondary forming die set **52**, and one of two cooling die sets **62**, respectively.

First, as illustrated in FIGS. **10**(*a*)-**10**(*c*), an upper die **43** of the primary forming die set **42** and an upper die **53** of the secondary forming die set **52** are moved down from their positions illustrated in FIG. **9**(*a*) in synchronization with each other, and an upper die **63** of one of the cooling die sets **62** also moves down from its position illustrated in FIG. **9**(*b*) at the same time as the upper dies **43** and **53**. A primary formed product p**1** is obtained from the steel sheet S with the primary forming die set **42**, a secondary formed product p**2** is obtained from the primary formed product p**1** with the secondary forming die set **52**, and the hardening of the secondary formed product p**2** is started with the secondary formed product p**2** held under pressure by the one of the cooling die sets **62**.

Next, as illustrated in FIGS. **11**(*a*)-**11**(*c*), while the secondary formed product p**2** is hardened with the upper die **63** of the one of the cooling die sets **62** moved down, the upper die **43** of the primary forming die set **42** and the upper die **53** of the secondary forming die set **52** move up in synchronization with each other without coordinating with the one of the cooling die sets **62**; the primary formed product p**1** plastically worked in the primary forming step **4** is separated from an upper pressing surface **43***a* of the upper die **43**; and the secondary formed product p**2** pierced in the secondary forming step **5** is separated from an upper pressing surface **53***a* of the upper die **53**.

Next, the secondary formed product p2 is removed from the secondary forming die set **52** and carried into the other cooling die set **62** by the second robot R2, the primary formed product p1 is simultaneously removed from the primary forming die set **42** and carried into the secondary forming die set **52** by an automatic conveyor (not shown), and the steel sheet S is then removed from the heating furnace **30** and carried into the primary forming die set **42** by an automatic conveyor (not shown).

Subsequently, as illustrated in FIGS. **12**(*a*)-**12**(*c*), the upper die **43** of the primary forming die set **42** and the upper die **53** of the secondary forming die set **52** are moved down in synchronization with each other, and an upper die **63** of the other cooling die set **62** also moves down at the same time as the upper dies **43** and **53**; thus, a primary formed product p1 is obtained from the steel sheet S with the primary forming die set **42**, a secondary formed product p2 is obtained from the primary formed product p1 with the secondary forming die set **52**, and the hardening of the secondary formed product p2 is started with the secondary formed product p2 held under pressure by the other cooling die set **62**.

Next, as illustrated in FIGS. **13**(*a*)-**13**(*c*), while the secondary formed product p2 is hardened with the upper die **63** of the other cooling die set **62** moved down, the upper die **43** of the primary forming die set **42** and the upper die **53** of the secondary forming die set **52** move up in synchronization with each other without coordinating with the other cooling die set **62**. Hardening is finished in the one of the cooling die sets **62** to obtain a final formed product P, and the upper die **63** of the one of the cooling die sets **62** also moves up at the same time as the upper dies **43** and **53**.

Subsequently, the final formed product P is removed from the one of the cooling die sets **62** by the third robot R3, the secondary formed product p2 is simultaneously removed from the secondary forming die set **52** and carried into the one of the cooling die sets **62** by the second robot R2, the primary formed product p1 is simultaneously removed from the primary forming die set **42** and carried into the secondary forming die set **52** by an automatic conveyor (not shown), and the steel sheet S is then removed from the heating furnace **30** and carried into the primary forming die set **42** by an automatic conveyor (not shown). As such, a primary forming step **4**, a secondary forming step **5**, and two hardening steps **6** are successively performed in sequence, thereby obtaining final formed products P on the production line.

As above, according to the second embodiment of the present invention, while a secondary formed product p2 is cooled with one of cooling die sets **62**, subsequent primary and secondary formed products p1 and p2 are obtained with primary and secondary forming die sets **42** and **52**, respectively, thereby doubling production through the entire production line **1** without increasing the number of primary forming die sets **42** and the number of secondary forming die sets **52** to achieve a compact production line **1** providing high productivity.

FIGS. **14**(*a*)-**14**(*c*) illustrate a primary forming die set **42** for use in a production line **1** according to a third embodiment of the present invention. In the third embodiment, only the structure of a lower die **44** of the primary forming die set **42** is different from that in the first embodiment, and the other elements are identical with those in the first embodiment; thus, only the difference between the third and first embodiments will be described hereinafter in detail.

A plurality of vertically extending recesses **44***c* are formed in the lower die **44** of the third embodiment, and each contain a separator **8**.

The separator **8** includes a supporting member **81** formed in the shape of a generally triangular pyramid, and a coil spring **82** for urging the supporting member **81** upward.

As illustrated in FIG. **14**(*a*), the supporting member **81** is urged upward by the coil spring **82** with the primary forming die set **42** opened, and protrudes upwardly beyond a lower pressing surface **44***a*. The supporting member **81** supports a steel sheet S carried from a heating furnace **30** to lift the steel sheet S, thereby separating the steel sheet S from the lower pressing surface **44***a*.

As illustrated in FIG. **14**(*b*), the supporting member **81** is pressed downward by the steel sheet S (an upper die **43**) with the primary forming die set **42** closed, and thus, descends against the spring force of the coil spring **82** so as to be contained in the recess **44***c*.

Furthermore, as illustrated in FIG. **14**(*c*), the supporting member **81** is urged upward by the coil spring **82** with the primary forming die set **42** opened, and thus, protrudes upwardly beyond the lower pressing surface **44***a*. The supporting member **81** lifts a primary formed product p1 to separate the primary formed product p1 from the lower pressing surface **44***a*.

A method for manufacturing a final formed product P from a steel sheet S by hot pressing along the production line **1** of the third embodiment is identical with that in the first embodiment except that the steel sheet S carried into the opened primary forming die set **42** is lifted by the supporting member **81** so as to be separated from the lower pressing surface **44***a*, that the supporting member **81** is contained in the recess **44***c* in synchronization with the closing of the primary forming die set **42**, and that the primary formed product p1 is lifted by the supporting member **81** in synchronization with the opening of the primary forming die set **42** so as to be separated from the lower pressing surface **44***a*; therefore, detailed description thereof is omitted.

As such, according to the third embodiment of the present invention, when a secondary formed product p2 is held under pressure by a cooling die set **62**, the primary formed product p1 formed with the primary forming die set **42** is never in contact with both the pressing surface **43***a* of the upper die **43** of the primary forming die set **42** and the pressing surface **44***a* of the lower die **44** thereof. This ensures the prevention of the heat release from both the pressing surface **43***a* of the upper die **43** and the pressing surface **44***a* of the lower die **44**, and avoids a situation where the temperature of the secondary formed product p2 becomes lower than the temperature at which hardening starts, thereby further reducing the energy consumed by, e.g., such a heating process for increasing the temperature of the primary formed product p1 as in Japanese Patent Publication No. 2007-136533 (paragraph 0028, FIG. 1) to reduce the running cost.

Although, in the third embodiment of the present invention, the lower die **44** of the primary forming die set **42** includes the plurality of separators **8**, a lower die **54** of a secondary forming die set **52** may include a plurality of separators **8**, and thus, the primary formed product p1 or the secondary formed product p2 may be separated from a lower pressing surface **54***a*.

Although the separators **8** of the third embodiment each include the single supporting member **81** and the single coil spring **82**, components of each of the separators **8** are not limited to the above components. For example, a bar-shaped member having a front end including a suction cup may be protruded downward from each of the upper dies **43** and **53**, and the primary and secondary formed products p1 and p2 may be drawn by the suction cup and suspended from the upper dies **43** and **53** so as to be each separated from a

corresponding one of the upper pressing surfaces **43***a* and **53***a* and a corresponding one of the lower pressing surfaces **44***a* and **54***a*.

Furthermore, although the separators **8** according to the third embodiment of the present invention each move the supporting member **81** up and down by extending and contracting the coil spring **82**, a method for moving the supporting member **81** up and down is not limited to the above method. For example, a cylinder extending or contracting in synchronization with the opening and closing of each of the primary and secondary forming die sets **42** and **43** may be used.

The invention claimed is:

1. A method for forming a steel sheet by hot pressing, the method comprising the steps of:

a primary forming step of obtaining a primary formed product by performing plastic working in which a heated steel sheet is pressed by upper and lower dies of a primary forming die set for a predetermined time period so as to be plastically deformed along a pressing surface of each of the upper and lower dies;

a secondary forming step of carrying the primary formed product into a secondary forming die set, and machining the primary formed product with upper and lower dies of the secondary forming die set for a predetermined time period to obtain a secondary formed product; and

at least one hardening step of carrying the secondary formed product into a cooling die set placed in a hydraulic press controlled by a servomotor, and allowing upper and lower dies of the cooling die set to hold the secondary formed product under pressure for a longer time period than the time period of each of the primary and secondary forming steps to obtain a hardened final formed product,

wherein:

the primary forming step, the secondary forming step, and the at least one hardening step are successively performed in sequence,

the at least one hardening step is configured so as to be performed independently without coordinating with the primary and secondary forming steps,

at least one of the primary or secondary forming die sets includes a temperature adjuster including a pipe inside the at least one of the primary or secondary forming die sets, a driver configured to circulate a heating medium through the pipe, and a temperature sensor connected to the at least one of the primary or secondary forming die sets,

at a production start time at which production starts on a production line including the primary and secondary forming die sets and the cooling die set, adjusting a temperature of the heating medium circulating through the pipe of the temperature adjuster so as to increase a temperature of at least one of the primary or secondary forming die sets to a temperature at which hardening of the secondary formed product starts while sensing the temperature of the at least one of the primary or secondary forming die sets via the temperature sensor, and

after increasing the temperature to the temperature at which hardening of the secondary formed product starts and between a start of hardening and an end of the hardening in the at least one hardening step:

the primary and secondary forming steps are both completed, the primary and secondary forming die sets are opened, the primary formed product plastically worked in the primary forming step and the secondary formed product machined in the secondary forming step are subsequently each separated from a pressing surface of at least one of the upper or lower die of a corresponding one of the die sets, and

the temperature of the at least one of the primary or secondary forming die sets is adjusted by adjusting, via the temperature sensor, the temperature of the heating medium circulation through the pipe while sensing, via the temperature sensor, the temperature of the at least one of the primary or secondary forming die sets such that:

when the temperature of the at least one of the primary or secondary forming die sets is lower than the temperature at which the hardening of the secondary formed product starts, the temperature of the at least one of the primary or secondary forming die sets is increased; and

when the temperature of the at least one of the primary or secondary forming die sets is higher than the temperature at which the hardening of the secondary formed product starts, the temperature of the at least one of the primary or secondary forming die sets is decreased.

2. The method of claim **1**, wherein:

the primary and secondary forming die sets operate in synchronization with each other by using corresponding mechanical presses.

3. The method of claim **2**, wherein:

the at least one hardening step comprises two hardening steps,

while the secondary formed product is cooled with the corresponding cooling die set in one of the two hardening steps, a secondary formed product subsequently machined with the secondary forming die set is carried into the corresponding cooling die set so as to be cooled in the other one of the two hardening steps, and

while the secondary formed product is subsequently cooled with the corresponding cooling die set in the other one of the two hardening steps, a hardened final formed product is removed from the corresponding cooling die set in the one of the two hardening steps.

4. The method of claim **1**, wherein:

at least one of a lower die of the primary forming die set in the primary forming step or a lower die of the secondary forming die set in the secondary forming step includes a plurality of separators,

the separators each include:

a supporting member having a sharp upper end, and

an urging mechanism configured to urge the supporting member upwardly, and

between a start of hardening and an end of the hardening in the hardening step, while the primary and secondary forming die sets are opened, a biasing force of the urging mechanism allows the supporting member to protrude upwardly beyond a pressing surface of the at least one of the lower die of the primary forming die set and the lower die of the secondary forming die set so that the at least one of the primary or secondary formed product is separated from both a pressing surface of the corresponding upper die and a pressing surface of the corresponding lower die by being lifted from the pressing surface of the corresponding lower die.

5. The method of claim **1**, wherein:

the temperature adjuster including the pipe inside the at least one of the primary or secondary forming die sets

and the driver configured to circulate the heating medium through the pipe is a forming die temperature adjuster,

the cooling die set includes a cooling die set temperature adjuster including a pipe inside the cooling die set and a driver configured to circulate cold water through the pipe of the cooling die set temperature adjuster, and

after the at least one hardening step has been completed and the cooling die set has been opened, a temperature of cold water circulating through the pipe of the cooling die set temperature adjuster is adjusted such that the cooling die set is decreased to a set temperature for hardening.

* * * * *